Observations and Modeling of the Green Ocean Amazon

Presented by Scot Martin at DOE Workshop, 26-27 July 2011, Washington, D.C.
Outline of Presentation

• WHY this experiment?
• WHERE will this experiment take place?
• WHEN will this experiment take place?
• WHAT instrumentation and facilities are part of experiment?
• HOW is the experiment organized?
Outline of Presentation

• WHY this experiment?
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Susceptibility and expected reaction to stresses of global climate change as well as pollution introduced by future regional economic development are not known or quantified at present time.

Cloud Life Cycle, Aerosol Life Cycle, Aerosol-Cloud-Precipitation Interactions, Carbon Cycle are all represented in this schematic.

**GoAmazon2014:** What is the effect of pollution on these cycles and the coupling among them?

Scientific Questions for GoAmazon2014

Note: Non-exhaustive selected list. Further development anticipated.

**Carbon Cycle** - improve Community Earth System Model (CESM) for land-atmosphere processes in the Amazon Basin, including aerosol-cloud-precipitation connections

- Objective - Reduce uncertainties in our knowledge of feedbacks between vegetation-hydrology that underlie the Amazon forest dieback hypothesis. The uncertain range of feedbacks at present leads to large differences in ESM predictions.

- Objective - Response of photosynthesis and transpiration, including BVOC emissions, to changes in the direct and diffuse components of incoming solar radiation, i.e., in the context of current and future scenarios of aerosols and clouds in the Amazon Basin.

**Aerosol Life Cycle** - accurate modeling of aerosol sources/sinks and aerosol optical, CCN, and IN properties, as affected by pollution of pristine tropical environments

- Objective - The interactions of the urban pollution plume with biogenic volatile organic compounds in the tropics, especially the impact on the production of secondary organic aerosol, the formation of new particles, and biogenic emissions of aerosols and their precursors.

- Objective - Influence of anthropogenic activities on aerosol microphysical, optical, cloud condensation nuclei (CCN), and ice nuclei (IN) properties in the tropics.
Cloud Life Cycle - development of a knowledge base to improve tropical cloud parameterizations in GCMs

- Objective - The transition from shallow to deep cumulus convection during the daily cycle of the Amazon Basin, with comparison and understanding to other environments.
- Objective - The role of landscape heterogeneity—the Manaus urban area as well as the 10-km-scale of river width—on the dynamics of convection and clouds (+carbon cycle)
- Objective - The evolution of convective intensity from severe storms in the dry season to moderate storms in the wet season.

Cloud-Aerosol-Precipitation Interactions - improvement of parameterizations of aerosol-cloud interactions in climate models

- Objective - Aerosol effects on deep convective clouds, precipitation, and lightning under different aerosol and synoptic regimes, including the roles of aerosols in changing regional climate and atmospheric circulation.
- Objective - Data-driven improvement of parameterizations of aerosol-cloud interactions in the climate models.
The theme uniting these objectives is the development of a data-driven knowledge base for predicting how the present-day functioning of energy, carbon, and chemical flows in the Basin might change, both due to external forcing on the Basin from global climate change and internal forcing from past and projected demographic changes in the Basin.

The ultimate goal is to estimate future changes in direct and indirect radiative forcing, energy distributions, regional climate, ecosystem functioning, and feedbacks to global climate.

In this regard, the presented objectives are representative, and further definition and broadening can be expected as the science team spins up prior to deployment.
Outline of Presentation

• WHY this experiment?
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Site Location

<table>
<thead>
<tr>
<th>Munícipios</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
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<td>16,725</td>
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<td>81,674</td>
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<td>84,656</td>
<td>82,308</td>
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<td>86,472</td>
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<td>NOVO AIRÃO</td>
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<td>8,304</td>
<td>7,580</td>
<td>7,002</td>
<td>6,516</td>
<td>14,630</td>
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</tr>
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<td>20,569</td>
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<td>24,360</td>
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<td>20,990</td>
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<td>24,858</td>
<td>26,004</td>
<td>26,847</td>
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<td>1,785,610</td>
<td>1,860,676</td>
<td>1,920,665</td>
<td>1,971,102</td>
<td>1,933,327</td>
<td>2,006,870</td>
<td>2,042,185</td>
</tr>
</tbody>
</table>

FONTE: IBGE

Acknowledgments: Rodrigo Souza, UEA
**Manaus: Vehicle Fleet 2010**

**FUEL MIX:**
- tractor, truck and bus: almost 100% diesel
- car and bikes: > 60% gasoline (*)

(*) Ethanol price is very high in Manaus and gasoline is preferred by the consumer.

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Quantity</th>
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</thead>
<tbody>
<tr>
<td>Motoneta</td>
<td>8,563</td>
</tr>
<tr>
<td>Motocicleta</td>
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<tr>
<td>Automóvel</td>
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<tr>
<td>Microônibus</td>
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<tr>
<td>Ônibus</td>
<td>5,807</td>
</tr>
<tr>
<td>Reboque</td>
<td>1,677</td>
</tr>
<tr>
<td>Semi-reboque</td>
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</tr>
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<td>Camioneta</td>
<td>18,812</td>
</tr>
<tr>
<td>Caminhão</td>
<td>14,631</td>
</tr>
<tr>
<td>Caminhão-Trator</td>
<td>2,019</td>
</tr>
<tr>
<td>Caminhonete</td>
<td>49,981</td>
</tr>
<tr>
<td>Ciclomotor</td>
<td>329</td>
</tr>
<tr>
<td>Trator rodas</td>
<td>48</td>
</tr>
<tr>
<td>Triciclo</td>
<td>100</td>
</tr>
<tr>
<td>Utilitários</td>
<td>2,403</td>
</tr>
<tr>
<td>Outros</td>
<td>109</td>
</tr>
</tbody>
</table>

452,300

*Fonte: DETRAN/AM*

Acknowledgments: Rodrigo Souza, UEA
## Manaus: Power Plant 2009: Fuel Oil

### Tabela 1 - Configuração do Parque Gerador do Sistema Manaus Amazonas - Agosto de 2009

<table>
<thead>
<tr>
<th>Usina</th>
<th>Potência do Sistema (MW)</th>
<th>Tipo de UG</th>
<th>Tipo de óleo</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nominal</td>
<td>Efetiva</td>
<td>Disponível</td>
</tr>
<tr>
<td>Geração hídrica</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balbina</td>
<td>250,0</td>
<td>250,0</td>
<td>250,0</td>
</tr>
<tr>
<td>Aparecida</td>
<td>198,0</td>
<td>172,0</td>
<td>75,0</td>
</tr>
<tr>
<td>Mauá</td>
<td>452,4</td>
<td>437,0</td>
<td>259,6</td>
</tr>
<tr>
<td>Geração Térmica</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Electron</td>
<td>120,0</td>
<td>102,2</td>
<td>0,0</td>
</tr>
<tr>
<td>Diesel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UTE*</td>
<td>149,8</td>
<td>120,8</td>
<td>94,2</td>
</tr>
<tr>
<td>TOTAL GERAÇÃO PRÓPRIA</td>
<td>1.170,6</td>
<td>1.081,3</td>
<td>678,45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRODUTOR INDEPENDENTE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breitener Tambaqui</td>
<td>83,5</td>
<td>60,0</td>
<td>60,0</td>
</tr>
<tr>
<td>Breitener Jaraqui</td>
<td>83,5</td>
<td>60,0</td>
<td>56,7</td>
</tr>
<tr>
<td>Manauara</td>
<td>85,4</td>
<td>60,0</td>
<td>60,0</td>
</tr>
<tr>
<td>Rio Amazonas</td>
<td>85,4</td>
<td>65,0</td>
<td>65,0</td>
</tr>
<tr>
<td>GERA</td>
<td>85,4</td>
<td>60,0</td>
<td>60,0</td>
</tr>
<tr>
<td>TOTAL DE COMPRAS</td>
<td>423,1</td>
<td>305,0</td>
<td>301,7</td>
</tr>
<tr>
<td>TOTAL GERAL DO SISTEMA</td>
<td>1.593,7</td>
<td>1.386,3</td>
<td>980,2</td>
</tr>
</tbody>
</table>

* inclui as UTE-Cidade Nova, UTE-São José e UTE-Flores

Fonte: Adaptado das informações obtidas junto a Eletrobras Amazonas Energia

### Acknowledgments
Rodrigo Souza, UEA

Hydropower

Oils of different grades
PTE - óleo leve "Para Turbina Elétrica"
PGE - óleo combustível "Para Gerador Elétrico"

OCA-1 = Óleo Combustível com Alto teor de enxofre = Fuel Oil with High Sulfur
• 111 by 60.8 km represented by this box.
• Wind speeds at 1 km altitude are typically 10 to 30 kph.
• T2→T3 transit time of 2 to 6 hr.
The deployment site is situated such that it experiences the extremes of:

(i) a pristine atmosphere when the Manaus pollution plume meanders; and

(ii) heavy pollution and the interactions of that pollution with the natural environment when the plume regularly intersects the site.
NO₂ Outflow from Manaus in Aug 2010 observed by OMI

Acknowledgments: Jun Wang, Univ. Nebraska
Large Point Source of Pollution in Manaus:  
*High-Sulfur Diesel for Electricity*
Outflow from Manaus first Crosses River: 2 to 10 km wide
Manaus Outflow Continues Across 60 km Forest
Arrival at AAA Large Pasture Site:

Location of ACRF Deployment
Seasonal Variability of Rainfall in Region

(a) Manaus k34

CO₂ Profiles in Manaus Region (BARCA)

A. Dry-season (16-22 November 2008)

Deviations show biosphere to be neutral or a weak CO₂ source (dry season)

Source: Saleska, Wofsy, et al. (personal communication)

B. Wet-season (15-27 May 2009)

Deviations show biosphere to be a strong CO₂ source (wet season)

Source: Saleska, Wofsy, et al. (personal communication)
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Dates of GoAmazon2014

AMF Operations (T3 ground site)

- 1 January until 31 December 2014
- Primaries
  - Brazil-side: INPA/LBA Office program manager (TBD)
  - USA side: Kim Nitschke (DOE LANL)
  - Scientific License: Rodrigo Souza (UEA) and Paulo Artaxo (USP)
Dates of GoAmazon2014

AAF Operations (aircraft)

• 40 flight days in period of 15 February until 31 March 2014

• 40 flight days in period of 1 September until 15 October 2014

• Primaries
  • Brazil-side: Karla Longo (INPE), Luiz Machado (INPE), and Gilberto Fisch (CTA)
  • USA side: Beat Schmid (DOE PNNL)
  • Scientific License: Karla Longo (INPE)
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ARM – Brazil Ground Site Operations Overview

Kim Nitschke
Field Instrument Deployments and Operations (FIDO) Office
Los Alamos National Laboratory
AMF1 – 7 x 20’ sea containers
1 full-time on-site technician

- Precision Spectral Pyranometer (PSP) x 2
- Precision Infrared Radiometer (PIR) x 2
- Shaded Black & White Pyranometer (B/W)
- Shaded Precision Infrared Pyrgeometer (PIR)
- Normal Incidence Pyrheliometer (NIP)
- Infrared Thermometer (IRT) x 2
- Multi-Filter Rotating Shadowband Radiometer (MFRSR)
- Narrow Field of View Zenith Radiometer (NFOV)
- Optical Rain Gauge (ORG)
- Anemometers (WND)
- Temperature/Relative Humidity Sensor (T/RH)
- Barometer (BAR)
- Present Weather Detector (PWD)
- Eddy Correlation Flux Measurement System (ECOR)
- Shortwave Array Spectrometer (SAS-He, SAS-Ze)
- Microwave Radiometer (MWR)
- Microwave Radiometer Profiler (MWRP)
- Microwave Radiometer 90/150 (MWR-HF)
- Doppler Lidar (DL)
- Ceilometer (CEIL)
- Balloon Borne Sounding System (BBSS)
- W-band ARM Cloud Radar - 95GHz (WACR)
- Ka-W Scanning ARM Cloud Radar (SACR)
- Atmospheric Emitted Radiance Interferometer (AERI)
- Total Sky Imager (TSI)
- Aerosol Observation System (AOS)
  - CCNC
  - PSAP
  - Nephelometers X 2
- Radar Wind Profiler – 1290MHz (RWP)
- Cimel Sunphotometer (CSPHOT)

LANL Solar Fourier Transform Spectrophotometer (FTS) (Dubey)
(OCO-2 validation)
Mobile Aerosol Observing System (MAOS) – 2 x 20’ sea containers (MAOS-A & MAOS-C)

2 x full time post-docs (supplied by ARM)

Guest operational personnel (approx. 5)

- SOnic Detection And Ranging (SODAR) System (1000 to 4000 Hz)
- Ultra-High Sensitivity Aerosol Spectrometer (enhanced)
- Dual Column Cloud Condensation Nuclei Counter (CCN)
- Single Particle Soot Photometer (SP2)
- Scanning Mobility Particle Sizer (SMPS)
- Photo-Acoustic Soot Spectrometer (PASS), 3 Wavelength
- Humidigraph (3 Relative Humidities with 3 single wavelength nephelometers)
- Humidigraph (Scanning Relative Humidity with 3 single wavelength nephelometers)
- Trace Gas Instrument System (Research-Grade)
- Particle Into Liquid Sampler-Ion Chromatography-Water Soluble Organic Carbon (PILS-IC-WSOC)
- Particle Soot Absorption Photometer (PSAP), 3 Wavelength
- Nephelometer, 3 Wavelength
- Condensation Particle Counter (CPC), 10 nm to >3000 nm particle size range
- Condensation Particle Counter (CPC), 2.5 nm to >3000 nm particle size range
- Hygroscopic Tandem Differential Mobility Analyzer (HTDMA)
- Proton Transfer Mass Spectrometer (PTRMS)
- 7-Wavelength Aethelometer
- Weather Transmitter (WXT-520)
- Aerosol Chemistry Speciation Monitor (ACSM)
“Intensive Airborne Research in Amazonia 2014”
(IARA-2014)

The ARM Aerial Facility (AAF) in Brazil
## Platform Position/Velocity/Altitude

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trimble DSM</td>
<td>Trimble TANS 10 Hz</td>
</tr>
<tr>
<td>position/velocity at 10 Hz</td>
<td>pitch/roll/azimuth</td>
</tr>
</tbody>
</table>

## Atmospheric State

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosemont 102 probe</td>
<td>Rosemount 1201F1</td>
</tr>
<tr>
<td>temperature</td>
<td>static pressure</td>
</tr>
<tr>
<td>Rosemount 1221F2 (3)</td>
<td>differential pressure (dynamic, alpha, beta)</td>
</tr>
<tr>
<td>GE-1011B chilled-mirror hygrometer</td>
<td>AIMMS-20</td>
</tr>
<tr>
<td>dew-point temperature</td>
<td>5-port air motion sensing: true air speed, altitude, angle-of-attack, side-slip, temperature, relative humidity</td>
</tr>
</tbody>
</table>

## Aerosol Measurements

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSI 3025 ultrafine condensation particle counter (UCPC)</td>
<td>TSI 3010 condensation particle counter (CPC)</td>
</tr>
<tr>
<td>total particle concentration (&gt;3 nm)</td>
<td>total particle concentration (&gt;10 nm)</td>
</tr>
<tr>
<td>aerosol particle size distribution (100 to 3000 nm)</td>
<td>aerosol particle size distribution (30 to 100 nm)</td>
</tr>
<tr>
<td>particle/soot absorption photometer (PSAP)</td>
<td>TSI Nephelometer</td>
</tr>
<tr>
<td>aerosol particle light absorption at 3 wavelengths</td>
<td>aerosol particle light scattering at 3 wavelengths</td>
</tr>
<tr>
<td>Aerodyne HR-ToF-AMS</td>
<td>DMT Dual Cloud Condensation Nuclei Counter (CCNC)</td>
</tr>
<tr>
<td>size-resolved particle composition</td>
<td>CCN concentrations at two supersaturations</td>
</tr>
<tr>
<td>sample stream of dry aerosol, sizes &lt; 2.5 μm</td>
<td></td>
</tr>
</tbody>
</table>

## Gas Measurements

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionicon Quadrupole PTR-MS</td>
<td>carbon monoxide analyzer</td>
</tr>
<tr>
<td>real-time VOCs</td>
<td>oxides of nitrogen instrument</td>
</tr>
<tr>
<td>Thermo environmental model 49i</td>
<td>Picarro cavity ringdown spectrometer</td>
</tr>
<tr>
<td>O3</td>
<td>CO, NO, NO2, NOy</td>
</tr>
<tr>
<td></td>
<td>CO2, CH4, H2O</td>
</tr>
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</table>
## IARA-2014: AAF G1 Payload

<table>
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<tr>
<th><strong>Cloud Measurements</strong></th>
<th>Instrument</th>
<th>HVPS-3</th>
<th>2DS</th>
<th>Fast-CDP</th>
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<tbody>
<tr>
<td>Measurement</td>
<td>cloud droplet size distribution (400 to 50000 μm)</td>
<td>cloud droplet size distribution (10 to 3000 μm)</td>
<td>cloud droplet size distribution (2 to 50 μm)</td>
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</tr>
<tr>
<td>Instrument</td>
<td>CIP</td>
<td>SEA WCM-2000</td>
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<td></td>
</tr>
<tr>
<td>Measurement</td>
<td>images of cloud particles (2 to 1000 μm)</td>
<td>liquid water content and total water content</td>
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</table>

<table>
<thead>
<tr>
<th><strong>Radiation</strong></th>
<th>Instrument</th>
<th>SPN-1 unshaded</th>
<th>SPN-1 unshaded</th>
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<tr>
<td>Measurement</td>
<td>downwelling shortwave radiation</td>
<td>Upwelling shortwave radiation</td>
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<table>
<thead>
<tr>
<th><strong>Other Measurements</strong></th>
<th>Instrument</th>
<th>SEA M300</th>
<th>weather radar</th>
<th>TCAS</th>
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</thead>
<tbody>
<tr>
<td>Measurement</td>
<td>central data acquisition/ display system</td>
<td>cockpit display of precipitation returns</td>
<td>traffic collision and avoidance system</td>
<td></td>
</tr>
<tr>
<td>Instrument</td>
<td>TAWS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement</td>
<td>terrain awareness and warning system</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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Brazil-Side Organizations

- CTA - Department of Science and Aerospace Technology, http://www.cta.br/
- UEA - University of the State of Amazonas, http://www1.uea.edu.br/
Main research foci:

- The changing environment of Amazonia
- Environmental sustainability and the sustainability of current terrestrial and aquatic production systems
- Variability and changes in climatic and hydrologic systems – feedback, adaptation and mitigation

Integrated and interdisciplinary investigations:

Yellow: multi-scale physico-chemical interactions at biosphere-atmosphere interface;

Red: physico-chemico-biological processes in aquatic and terrestrial ecosystems and their interactions;

Blue: the social dimensions of environmental change and the dynamics of land cover change

Acknowledgments: Laszlo Nagy, INPA/LBA
<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Institution</th>
<th>Link</th>
</tr>
</thead>
</table>
GoAmazon2014: Known and Planned Activities

Cloud Life Cycle Project
GPM-CHUVA
Leader: Luiz Machado

IARA-2014
DOE AAF Deployment

NASA Satellite Science
Coordinators: Loretta Mickley and Jun Wang

An Aerosol Life Cycle Project
T2 → T3 Lagrangian experiment accompanying IARA-2014
Coordinator: Jian Wang

DOE AMF Deployment

Aerosol-Cloud-Precipitation Interactions
Aeroclima
Leader: Paulo Artaxo

Cloud Life Cycle Project
BEACHON
Leader: Alex Guenther

Aerosol Life Cycle Project

More activities expected
(some DOE, some not DOE):
Cloud Life Cycle, Aerosol-Cloud-Precipitation Interactions, Carbon Cycle, international partners, …

iLEAPS IGAC ACPC
Point of contact: Meinrat Andreae
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Google Group:

http://groups.google.com/group/GoAmazon2014

Websites:

DOE maintained: http://campaign.arm.gov/goamazon2014/

PI maintained: http://www.seas.harvard.edu/environmental-chemistry/GoAmazon2014/